Migration routes and stopover sites of Pallas's Gulls *Larus ichthyaetus* breeding at Qinghai Lake, China, determined by satellite tracking

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The migration routes, stopover sites, wintering areas, and site fidelity of five Pallas's Gulls captured in July 2006 at Qinghai Lake, Qinghai, western China, are documented. Each gull was captured after the breeding season using leg nooses and fitted with a 12 g solar-powered Platform Transmitter Terminal. One bird died within a month of capture near the release site, two birds completed the return journey between the breeding and wintering grounds on three occasions, and two birds completed the return migration twice. After departing from Qinghai Lake, migration to the wintering areas took an average of 99 days and covered a mean distance of 2,990 km. Return migration to Qinghai Lake in spring averaged 38 days and covered a mean distance of 2,556 km. In 2006–2009, the gulls left the breeding grounds between 2 and 14 August, stopping at 1 4 sites en route to the wintering areas, which they reached between 3 November and 3 December. In 2007–2009, returning birds departed from the wintering areas and stopped at 1 2 sites before reaching Qinghai Lake. Wetlands at Donggeicuona, Zhaling and Eling Lakes, Keluke Lake, Qinggeda Lakes, Xinjiang, and wetlands along the Yellow River, Ningxia, were most extensively used. The number of Pallas's Gull breeding at Qinghai Lake has already fallen dramatically from over 87,000 in the 1970s to about 15,000 in present times. Rapid economic development on the Qinghai–Tibet plateau (Qinghai province and the Tibet autonomous region), particularly for tourism, poses serious threats to the fragile ecosystems associated with the wetlands where gulls stop over, with some wetlands became unsuitable for the gulls during the period of this study. Conservation measures must be put in place urgently to protect the fragile wetland ecosystems on the Qinghai–Tibet plateau.

INTRODUCTION

The Pallas's (or Great Black-headed) Gull *Larus ichthyaetus* breeds from the Danube Delta in Romania eastwards across large areas of Central Asia to western China, where the lakes of the Qinghai–Tibet plateau hold most of the Chinese breeding population (Liao *et al.* 1984, Jian *et al.* 1991, Wang 1991). It breeds on small islands, often in large numbers, and forages primarily on these lakes; other islands and shorelines serve as daytime roosts. Qinghai Lake, lying on the northern part of the Qinghai–Tibet plateau at 3,260 m, is home to approximately 15,000 Pallas's Gulls (Liao *et al.* 1984, Zhang *et al.* 2008a).

With a total area of 4,392 km^2, Qinghai Lake is the largest saline lake in China and one of the most important breeding and stopover sites for waterbirds along the Central Asia–India Flyway (Zhang & Yang 1997). Attempts have been made to determine where Pallas's Gulls from Qinghai Lake spend the winter, and a total of 711 fledglings were marked with metal rings in the period 1983–1985. Of these, just two were recovered; one at Liuyuan, Gansu province, China, and the other in Assam, India, this latter location being an important stopover site during autumn migration (Zhang & Yang 1997, Muzaffar *et al.* 2008). To further our understanding of the migration routes followed, Platform Transmitter Terminals (PTTs) were fitted to five Pallas's Gulls at Qinghai Lake in July 2006 and their movements monitored until January 2010. The specific objectives of this study were to: (1) determine migration routes and stopover sites used by Pallas's Gulls breeding at Qinghai Lake; (2) explore possibilities in changing migration routes; (3) determine wintering locations; (4) document fidelity at major stopover sites.

This research will contribute to the conservation of the wetlands on the Qinghai–Tibet plateau, areas that have been threatened by human encroachment leading to habitat damage in recent years.

STUDY AREA AND METHODS

Capture sites

At Qinghai Lake, Pallas's Gulls nest on two islands—about 1,400 birds on Haixinshan and 14,000 on Sankuaishi (Zhang *et al.* 2008a)—and forage at Quanwan, Buhahekou, Sankuaishi and Heimahe (Zhang *et al.* 2008b). Five PTTs were fitted, two to birds captured at Quanwan (36.945°N 99.623°E), one at Buhahekou (36.958°N 99.837°E) and two at Sankuaishi (36.797°N 99.918°E).

Gull capture, harnessing and transmitters

In order to avoid disturbing nesting birds and fledglings in May and June, the birds were captured in July during the post-breeding period using leg nooses (Zhang *et al.* 2008b). Each bird was fitted with a solar-powered PTT (12 g Microwave Telemetry PTT-100), weighing 0.6–0.8% of the bird's body mass, and released immediately. PTTs were attached dorsally between the wings by fashioning a harness of 0.6 cm wide Teflon ribbon (Nagendran *et al.* 1994). This timetable allowed the gulls time to adjust to their transmitters before migration. The birds were identified as G1 to G5. Duty cycles for all PTTs were 10 hours on, 48 hours off (Table 1).

Satellite location data and statistical analysis

The Argos location and data collection system (ARGOS 2007) was used to track movements of the gulls. Location classes (LC) were used to reflect location accuracy (ARGOS 2007). Collecte Localisation Satellites (CLS) report a 1-sigma error radius of

Table 1. Details of Pallas's Gulls fitted with PTTs at Qinghai Lake, Qinghai, China.

Bird	PTT tracking commenced	Capture site	Number of days PTT functioned*
G1	7 July 2006	Quanwan	1,288
G2	11 July 2006	Sankuaishi	1,182
G3	24 July 2006	Buhahekou	671
G4	11 July 2006	Sankuaishi	859
G5	10 July 2006	Quanwan	25

*Duty cycles for all PTTs were 10 hours on/48 hours off.

1,000 m, 350–1,000 m, 150–350 m, and 150 m for LC 0, 1, 2, and 3, respectively. Auxiliary LCs A, B, and Z are not assigned accuracy estimates by CLS (Takekawa *et al.* 2010). As recommended by Keating *et al.* (1991) and ARGOS (2007), only LCs 3, 2, 1 and 0 were used in this study to determine migration routes, so an accuracy of 1,000 m for all data is assumed for LC 1 and above. According to the duty cycle of the PTTs and a study by Takekawa *et al.* (2010), a migratory stopover site was defined as an area where birds moved less than 20 km in a time period e" 48 hours.

Because the PTTs did not transmit continuously, the date of departure and arrival was defined as the median date between the last point at the previous location and the first point at the new location (Zhang *et al.* 2011a). If the gap between dates was greater than ten days due to no data or LCs A, B, and Z data received from ARGOS, then departure or arrival dates, or length of stay, were not calculated (Martell *et al.* 2001). We used the c^2-test to determine significant differences in the migration distances of the tagged gulls between years. The LCs 3, 2, 1 and 0 were also used in kernel density analysis on locations to establish home range selection at some important stopover sites.

RESULTS

Of the five Pallas's Gulls tracked, four left Qinghai Lake successfully, while one died close to the site where it was released, most likely from avian predation (Table 1). Of the four surviving gulls, two completed autumn and spring migration on three occasions, and the other two completed autumn and spring migration twice.

Migration timing

In each year from 2006 to 2009, the gulls departed from their breeding areas between 2 and 14 August and spent an average of 99 days on migration or at stopover sites (range 81–116 days) before arriving at wintering grounds between 3 November and 3 December (Tables 2 & 3). From 2007 to 2009, birds departed from their wintering sites between 18 February and 30 March and migrated north-eastwards for an average of 38 days (range 7–69), and returned to Qinghai Lake between 23 March and 2 May.

Autumn migration routes

In autumn, the gulls departed the breeding areas in four different directions (south-west, west, north-west and north-east). During the monitoring period (2006–2009), G1 and G2 completed a full annual migration cycle (both autumn and spring) three times, G3 and G4 completed it twice. Three gulls (G2, G3, G4) dispersed and wandered for over two months to wetlands to the west and north of Qinghai Lake, including Keluke Lake, Qinghai (250 km west of Qinghai Lake, average duration of stay 43 days), Qinggeda Lake, Xinjiang (1,300 km north-west of Qinghai Lake, average 68 days), Hongyashan reservoir, Gansu (290 km south-east to Qinghai Lake, 79 days), and Yellow River wetlands, Ningxia (550 km north-west of Qinghai Lake, 17 days) (see Figures 1–4). All four gulls flew over the T'ang-ku-la mountains, passed by the Qiangtang wetlands in Tibet, such as Hangcuo Lake (5 days) in Nagqu, Tibet, and then crossed the Himalayas to reach wintering sites on the shores of the Bay of Bengal.

The Bay of Bengal, with extensive areas of coastal mudflats, is an important wintering site for Pallas's and other gull species, from early November to mid-March. The birds favour areas close to Chittagong, Magdhara, Bhubaneswar, Rajahmundry and Dhamra.

Table 2. Departure and arrival dates of Pallas's Gulls tagged with PTTs during 2006–2009 at Qinghai Lake, Qinghai, China.

		Spring		Autumn	
Bird	Years	Departure date from wintering sites	Arrival date at Qinghai Lake	Departure date from Qinghai Lake	Arrival date at wintering sites
G1	2006			14 August	3 November
	2007	1 March	1 April	14 August	4 November
	2008	8 March	7 April	A	15 November
	2009	18 February	5 April	8 August	10 November
G2	2006			2 August	4 November
	2007	18 March	12 April	8 August	14 November
	2008	8 March	26 April	4 August	16 November
	2009	25 March	26 April		
G3	2006			9 August	3 December
	2007	30 March	15 April	—	—
	2008	8 March	2 May	—	—
G4	2006			3 August	22 November
	2007	17 March	23 March	14 August	24 November
	2008			5 August	23 November

A = Could not be determined due to insufficient data.

Table 3. Stopover sites and length of stay of Pallas's Gulls tagged with PTTs at Qinghai Lake, Qinghai, China during 2006–2009.

		Spring		Autumn	
Bird	Year	Stopover sites	Days	Stopover sites	Days
G1	2006			Chahanwusu River	22
				Zhaling Lake and Eling Lake	49
	2007	Yellow River, Ningxia	21	A	—
	2008	Yellow River , Ningxia	26	Zhaling Lake and Eling Lake	30
				Hang Lake	5
	2009	Yellow River, Ningxia	26	Donggeicuona Lake	7
				Zhaling Lake and Eling Lake	45
G2	2006			Keluke Lake	88
	2007	Keluke Lake	49	Keluke Lake	19
				Qinggeda Lake	52
	2008	Keluke Lake	66	Keluke Lake	21
				Qinggeda Lake	52
	2009	Keluke Lake	26		
G3	2006			Hongyashan reservoir	
				Yellow River, Ningxia	7917
	2007	—	—	—	—
	2008	Yellow River, Ningxia			
		Hongyashan reservoir	412		
G4	2006			Qinggeda Lake, Xinjiang	83
	2007	—	—	Qinggeda Lake, Xinjiang	83
	2008	Longyangxia reservoir	3	—	—
	2009				

A = could not be determined due to insufficient data.

Spring migration routes

After departing from their wintering areas, the gulls migrated north-east and crossed the Himalayas before entering Tibet, where they paused briefly before crossing the T'ang-ku-la mountains. At this point, G1, G2 and G3 paused at sites where they had lingered during post-breeding dispersal: G1 at the Yellow River wetland in Ningxia for between 21 and 26 days, G2 at Keluke Lake for between 26 and 66 days and G3 at Hongyashan reservoir in Gansu for 12 days. The other bird, G4, stopped at Longyangxia reservoir for three days and Keluke Lake for several days before returning to Qinghai Lake.

Migration distances

After departing from Qinghai Lake, the tagged gulls stopped at up to four sites and travelled an average of 2,990 km (range 1,810–3,980 km) before reaching their wintering areas. Distances travelled were not significantly different between years for the same tagged individuals (Table 4) ($c^2 = 0$, $df = 3$, $p = 1.000$), while they were significantly different among the marked gulls in the same year or

Figure 1. Migration routes and stop-over sites of Pallas's Gull (G1) from autumn 2006 to winter 2009.

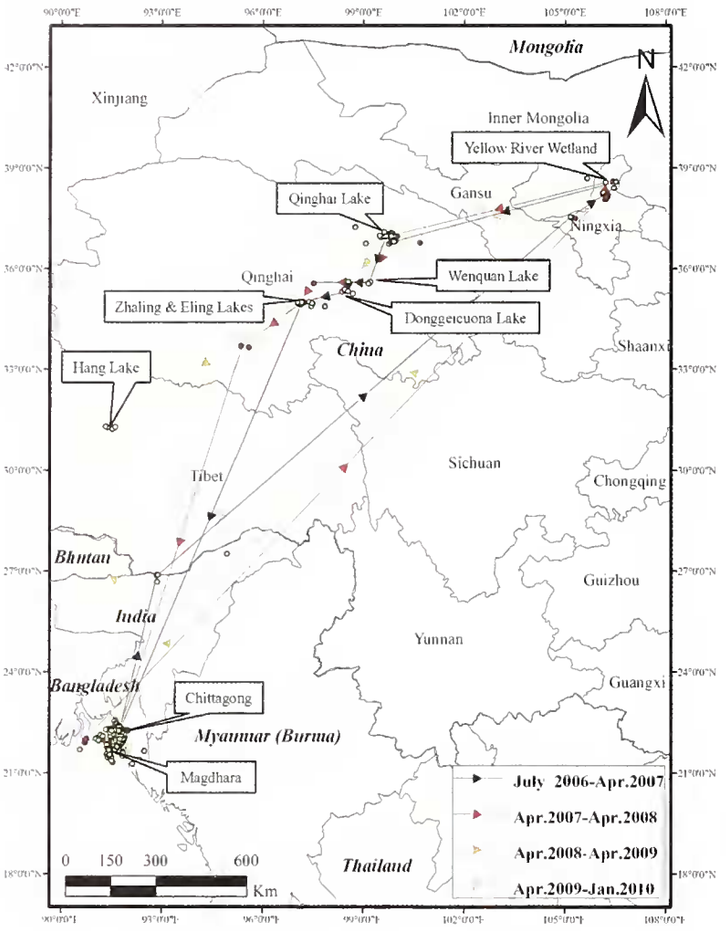

Figure 2. Migration routes and stop-over sites of Pallas's Gull (G2) from autumn 2006 to autumn 2009.

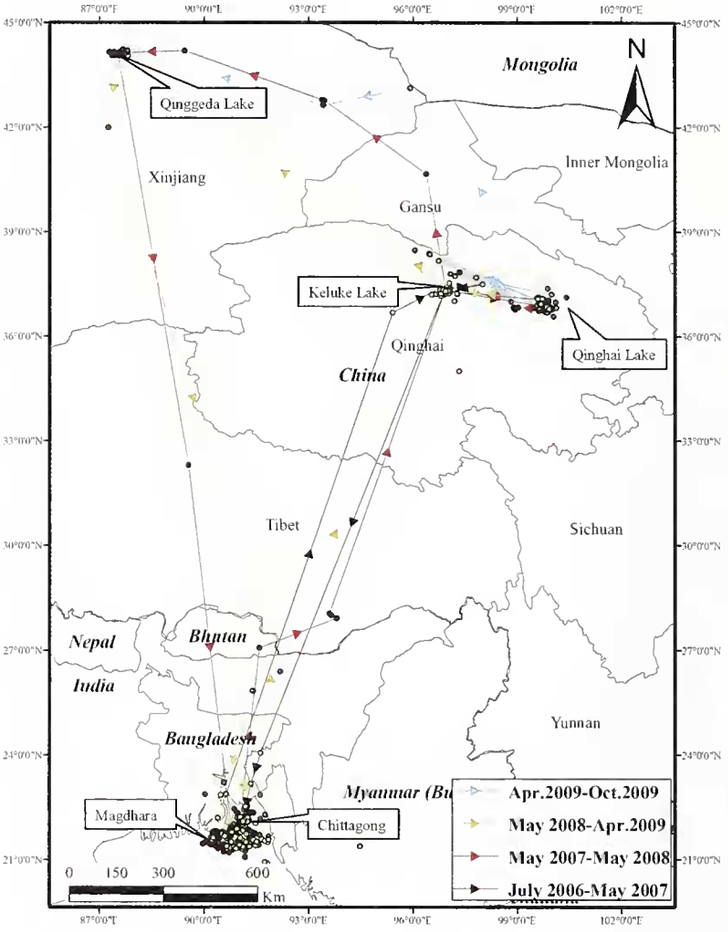

Figure 3. Migration routes and stop-over sites of Pallas's Gull (G3) from autumn 2006 to spring 2008.

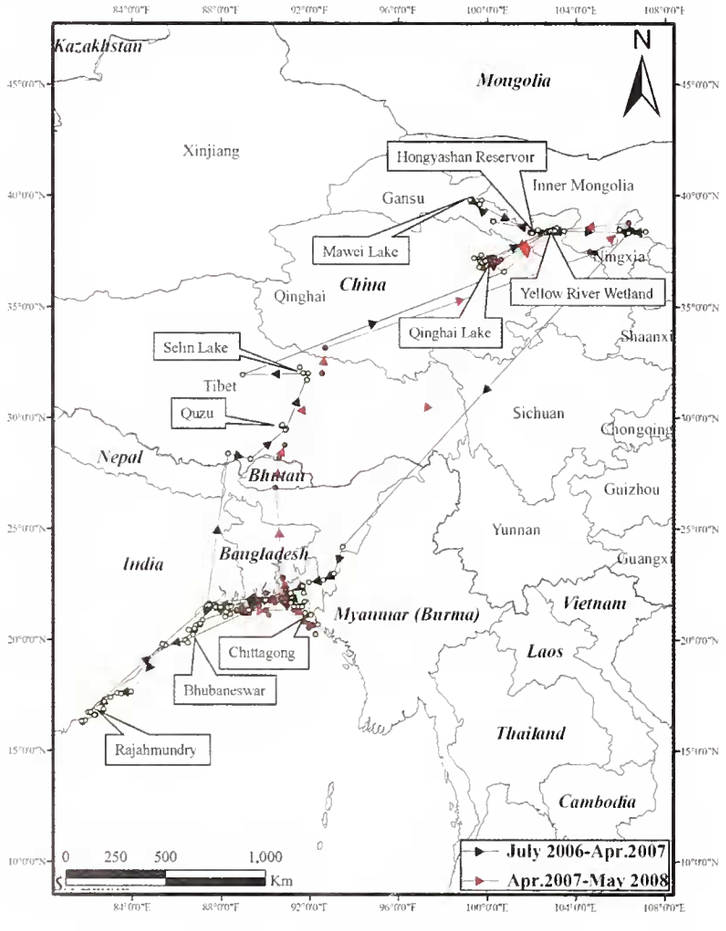

Figure 4. Migration routes and stop-over sites of Pallas's Gull (G4) from spring 2007 to spring 2008.

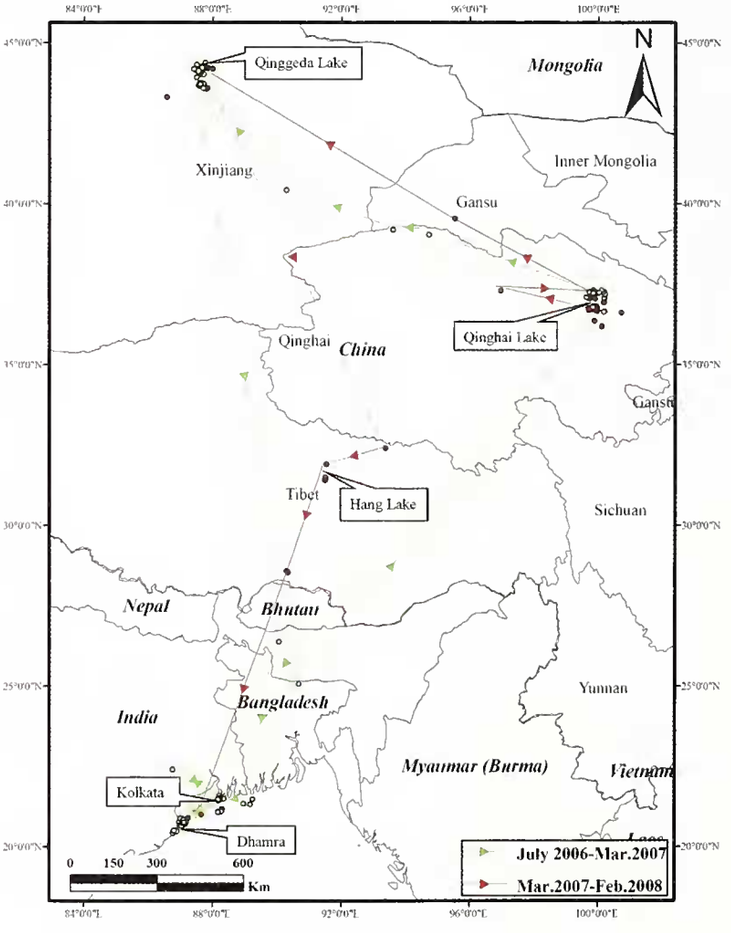

Table 4. Distances travelled by Pallas's Gulls tagged with PTTs at Qinghai Lake, Qinghai, China, during autumn and spring migration.

Bird	Spring migration (km)			Mean distance (km)	Autumn migration (km)				Mean distance (km)
	2007	2008	2009		2006	2007	2008	2009	
G1	2,970	2,900	2,880	2,917	1,860	1,900	2,030	1,810	1,900
G2	1,980	2,340	2,510	2,277	2,050	3,890	3,980	A	3,307
G3	2,700	2,800	A	2,750	3,680	A	A	A	A
G4	2,180	2,360	A	2,270	3,950	3,970	3,780	A	3,900

A = could not be determined due to insufficient data.

between years (f = 10.829, df = 9, p = 0.007). Gulls G2 and G4 travelled much further—3,307km and 3,900 km respectively—than G1 (average 1,900 km) (Table 4).

During spring migration, one or two stopover sites were used, and the mean distance travelled was 2,556 km (range 1,980–2,970 km) before reaching their breeding area. As in autumn migration, the distances travelled during spring migration were not significantly different between years for the same individuals (c^2 = 0, df = 3, p = 1.000), but were significantly different among different gulls in the same year or between years (f = 10.024, df = 9, p = 0.009). The distance travelled by G1 (mean 2,917km) and G3 (mean 2,720 km) was substantially more than by G2 (mean 2,277km),) and G4 (mean 2,270 km) (Table 4).

Fidelity to stopover sites

After leaving Qinghai Lake, a variety of stopover sites were selected by the gulls (Table 3, Figures 1–4) These sites included Donggeicuona Lake (G1, August and September), Zhaling and Eling Lake (G1, October), Keluke Lake (G2, August), Yellow River wetlands (G3, October) and Qinggeda Lake (G4, September and October)) during the autumn migration, and the Yellow River wetlands (G1, March April) and Keluke Lake (G2, March April) during the spring migration, indicating strong stopover site fidelity by the gulls. But stopover duration varied greatly between individuals and/or between different years for the same individuals. For example, G2 stayed at Keluke Lake for 88 days during autumn 2006, but for just 19 days in 2007 and 21 days in 2008, before heading north-west to the Qinggeda Lake, Xinjiang, where it remained for over one month between August and October in 2007 and 2008 (Table 3).

DISCUSSION

In the 1970s, Pallas's Gull nested at five sites at Qinghai Lake (Haixinshan, Sankuaishi, Niao island, Sha island and Luci island) and the numbers breeding were much higher than those found during this study. For example, Liao *et al.* (1984) reported 12,150 nests at Niao island and 14,000 nests at Luci island, while Li *et al.* (1989) reported over 87,500 gulls in July at Qinghai Lake. Zhang *et al.* (2008a) did not record any nests at Niao island, Sha island, or Luci island. During this study, in all 15,400 breeding birds were counted at Haixinshan and Sankuaishi, indicating that the breeding population in this area has decreased dramatically.

Two gulls marked with metal rings at Qinghai Lake in the early 1980s have been recovered: one at Liuyuan in Gansu, western China, in October 1983 and the other in Assam, north-east India, in March 1984 (Zhang & Yang 1997), the latter being an important stopover site (Muzaffar *et al.* 2008). Based on the finding from the present study, we suspect the Liuyuan bird probably died during a stopover en-route to Xinjiang. The Assam bird, also found dead, may have left the Bay of Bengal, a known major wintering site (Zhang & Yang 1997, Muzaffar *et al.* 2008) and died while returning to the breeding grounds.

The gulls depart in groups at different times over a period of about a month. After departing from Qinghai Lake, some gulls did not fly south immediately to their wintering sites, but wandered in nearby areas for as long as a month. Natural wetland habitats, such as Zhaling and Eling Lakes at Madoi, Qinghai, are virtually unaffected by human activites (Hong *et al.* 2008), while other sites which were utilised for short stopovers, such as the Yellow River wetlands, Hongyashan reservoir and Qinggeda Lake, are facing serious challenges and threats, including over-fishing, water development projects and tourism (Wei & Guo 2000, Song *et al.* 2003, Yao *et al.* 2008).

It is well known that animals may change their migration routes due to environmental deterioration at stopover sites, especially those relating to human disturbance, habitat loss and decrease in food resources (Shepherd & Boates 1999, Schaub & Jenni 2001). In this study, G2 changed its migration routes during autumn migration in 2007, when a road around Keluke Lake was extended into its home range there (Zhang *et al.* 2011b). The road improvement was aimed at increasing local income by attracting more tourists, but with the increase in the number of tourists, land vehicles, boats and yachts, the lake is no longer suitable for foraging gulls (Hao & Ju 2011, Zhang *et al.* 2011b).

During spring migration, higher-altitude wetlands such as Donggeicuona, Zhaling and Eling lakes are ice-covered and gulls are unable to forage. Instead, they fly directly to more suitable sites in warmer areas and at lower altitude, such as the Yellow River wetlands and Keluke Lake, before reaching Qinghai Lake (Figure 1–4). Migration routes and the duration of stopover periods on the Qinghai–Tibet plateau primarily depend on external factors, in particular the prevailing weather conditions that may enable or prevent foraging, especially at higher altitudes (Eichhorn *et al.* 2009, Köppen *et al.* 2010). For example, the duration of stay by G1 and G2 at Keluke Lake and the Yellow River wetlands during spring migration was possibly related to ground surface temperature at Qinghai Lake.

There is little or no persecution of Pallas's Gulls in the breeding areas by the indigenous Tibetan people who traditionally consume 'neither fish nor fowl,' and wildlife hunting is contrary to their religious belief. Waterbirds and wetlands surveys on the Qinghai–Tibet plateau in 2006–2011 revealed that wetland degradation on the plateau was caused mainly by mineral exploration in major wetlands in Shenzha county, Nagqu prefecture, as well as other areas, together with related road development and wetland drainage, critically threatening the plateau's fragile wetland ecosystem (Ying *et al.* 2009), to the extent that some wetlands are no longer suitable for breeding waterbirds (Yu *et al.* 2011). In addition, proposed petroleum extraction and airport construction by local governments in this region pose further threats to the wetlands and waterbirds, leading to increasing conflict with wildlife and wetlands conservation. It seems inevitable that further economic development in the Changtang region will take place (Sun *et al.* 2011, Lai *et al.* 2012).

As tourism continues to expand the local standard of living will continue to rise, with local governments continuing to invest enthusiastically in infrastructure and urban expansion on the Qinghai–Tibet Plateau (Jian *et al.* 2011). If unregulated and unchecked this will lead to damage and drainage of wetlands. As remaining wetlands and other wildlife habitats become fragmented, wildlife will find survival increasingly difficult. To protect the fragile wetland ecosystem on the Qinghai–Tibet plateau, it is recommended all development projects are carefully planned, reviewed and managed. Development of some areas used for breeding and stopovers during migration, such as Zhaling Lake, Eling Lake and Keluke Lake, must be restricted or prohibited, and

these vital habitats preserved so that the long-term survival of gulls and other wildlife can be secured.

A study of factors that may have been responsible for the decline in Pallas's Gull breeding numbers is needed. One possible reason for this decline is increasing human disturbance at Qinghai Lake, including the impact of increasing numbers of tourists during the breeding season from May to August—for example, activities now include an annual international cycle race held over two weeks in July.

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